RELATIONSHIP BETWEEN EATING PATTERNS AND PERFORMANCE OF FEEDLOT STEERS

By

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NOMENCLATURE

ADG	average daily gain
F:G	feed to gain ratio
BW	body weight
DM	dry matter
DMI	dry matter intake
h	hour
d	day
wk	week
yr	year
cm	centimeter
m	meter
kg	kilogram
RF	radio frequency
DVI	daily variation in intake
ME	metabolizable energy
ER	eating rate

CHAPTER I

INTRODUCTION

During the past century, the cattle industry has undergone several changes. Cattle types have changed numerous times, and technology has brought production to a new level. Research has broadened our minds and made producers aware of the possibilities for further improvements in the efficiency of beef production. Implants, feed additives and improved grazing management have increased efficiency and allowed us to produce more product with lower economic input. In today's market, these changes are needed to help the beef industry remain competitive with pork and poultry. To be competitive, every opportunity to decrease costs and improve efficiency must be explored. One of the largest costs associated with beef production is the cost of feed. If producers are able to decrease the amount of feed required for production, they will ultimately increase their profits. Throughout the past several decades, beef cattle types have been selected to result in larger cattle with greater feed consumption. Historically, feed intake has been reported as an average measure from a pen of cattle, and individual intake was only measurable from individually housed animals. Recent advances in technology have provided the GrowSafe System, which will allow the measurement of individual animal intake within a pen setting. The GrowSafe System will allow for a more accurate depiction of how cattle actually consume feed in a commercial setting. The GrowSafe System can also facilitate researchers to better understand the relationship between performance and the many variables that affect performance. The GrowSafe System was utilized to conduct the research contained in this thesis, in order to evaluate the relationship between performance and feeding patterns of feedlot steers.

CHAPTER II

REVIEW OF LITERATURE

With the transition to a global economy, beef production will become more vertically integrated, and accurate, timely information will be the foundation for management decisions that will ultimately dictate profitability. In the past, animal identification was accomplished by external marks such as brands and tattoos, however, these methods are labor intensive and unable to readily link information between cow/calf producers, backgrounders, feedlots, packers, retail outlets and consumers (Augsburg, 1990). More recent technology exists that allows for identification of individual animals throughout each production phase of the entire industry. The information network that is being created has the capability to enable the beef industry to compete more successfully with the vertically integrated swine and poultry industries, and ultimately capture a larger market share.

For years cattle producers have used performance traits to help increase their output and ultimately their profit margins. Average daily gain has typically been the performance measurement that producers have utilized in selection criteria for replacements. However, it has been recognized that more efficient animals will yield higher profits, and as a result producers have started to view feed efficiency as a variable that should be included in selection criteria. Typically, feed efficiency is expressed as kg of feed consumed per kg of BW gained. Therefore, the smaller the value, the more efficient the animal is at converting feed into BW gain. There are several factors that can make one animal more efficient than another animal. For example, maintenance energy requirements can differ between animals causing some animals to be more efficient. In the beef cattle industry, feed efficiency (F:G) is typically measured as the average efficiency on a pen basis. However, there can and will be large variations among individual animals in a pen. With measurements taken from the pen average, the industry has not been able to correctly select for and improve the genetics of animals, because one does not know how much one animal eats compared to another animal within the same pen. In order to measure feed efficiency in individual animals, animals would have to be penned individually. However, this is not a realistic option in commercial facilities.

Profitability is a function of both inputs and outputs, with the consideration for reducing inputs to improve efficiency of the entire system and increase profitability. One manner in which profitability can be increased is to identify, with the use of technology, those animals that are more efficient. Until recently, confining individual animals in a single pen or in a tie stall was the only means by which measurements such as feed intake could be obtained to determine the efficiency on an individual animal. However, confining animals for the measurement of individual intake can alter behaviors such as feeding and drinking (Albright and Arave, 1997), and diminishes opportunity for social interaction among animals that may occur in typical feedlot pens. As a result, it would be difficult to directly compare the data from group-housed animals to that of individually-housed animals. As technology advances, several systems have been developed to allow data collection from individual animals housed within a penned group.

Feeding Systems

Calan Gates. Feeding behavior information has been an interest to researchers for decades. This information has been collected with systems, some as simple as a strain gauge mounted to record the amount of feed consumed in a meal event (Suzuki et al., 1969), while others involve complex electrical components. Electronic gates such as the Calan(r) system (American Calan Inc., Northwood, NH) consist of a series of gates that are controlled by individual transponders worn around the neck of each animal. Once an animal approaches the proper gate, that gate will unlock and allow the animal to push the gate open and eat from the assigned feeder. By measuring feed allotments and orts from each feeder, individual intake can be obtained. During the two to three week learning period, cattle are gradually restricted access to feeders, narrowing down the choices to their assigned feeder. The cattle are penned as a group with the Calan gate system, however this assigned feeding spot at the bunk most likely alters the feeding dynamics to some degree. The Calan headgate system's main advantages are that the system and replacement parts are inexpensive, a variety of diets can be fed simultaneously and it has a high degree of accuracy (Cole, 1995). The major disadvantages are the extensive labor requirements, difficulties in training animals, manual measurement of feed intake, and in the event that there is mechanical error, the animals cannot eat because the gate is rendered inoperable.

Pinpointer Systems. The Pinpointer system (Pinpointer, UIS Corporation, Cookville, TN) uses a transponder worn around the neck of the animal, which identifies that animal as it enters the feeding stall. A microprocessor continuously monitors the disappearance of feed, as well as duration and frequency of attendance while the animal is in the stall. While this system is very user friendly and accurate (Cole, 1995), the main disadvantage is that it alters feeding patterns and competitive feeding behavior of the animal (Pond et al., 1995). This system also requires significant time to train animals and staff, and there is a drop out rate among animals in that not all cattle can be trained to use the system. Other disadvantages are that it has a high initial cost, and is limited to use with dry diets that will flow through the feed hopper (Cole, 1995). There are also limitations to the number of animals one can simultaneously feed with the Pinpointer system. Cole (1995) indicated that no more than 15 finished weight steers may be used at one time.

GrowSafe System

One method of documenting individual animal performance and behavior information involves the use of radio frequency (RF) systems. Radio frequency is capable of monitoring ingestive behavior such as eating and drinking. These behaviors have been identified as early indicators of morbidity, poor performance, and reduced feed intake in feedlot cattle (Basarab et al., 1997; Sowell et al., 1998, 1999; Basarab et al., 2000; Gibb and McAllister, 1999). Radio frequency systems have a low frequency radio signal that transfers information between a transponder with a unique identification code and an antennae that collects the signal and transfers it to a decoder. Radio frequency does not require a clear line of sight for the transfer of information to occur. Most RF systems currently sold will transmit a frequency between 120.0 and 134.2 kHz and are capable of penetrating wood, body tissue and plastic but will not transmit through metal in items such as chutes, buildings and handling systems. Depending upon the manufacturer, these systems will broadcast a distance of 8 to 100 cm. The broadcast distance and readability depend upon several factors such as the magnetic strength of the antennae, the amount of electromagnetic interference in the environment, transponder power requirements, size of the transponder and the orientation of the transponder to the antennae (Geers et al., 1997). A larger transponder or antennae will result in a longer read distance. Electric motors and ungrounded metal around the antennae can cause false readings or negate the ability of the transponder to be read (Schwartzkopf-Genswein et al., 1999).

Radio-frequency systems will employ one of two types of transponders, active or passive. Active transponders are powered by an internal battery, which makes them impractical for long-term use in the livestock industry. Passive transponders are a much better choice due to the fact they derive their power from the antennae. Most passive transponders are encapsulated in glass and will range in size from 2.2 mm to 3.6 mm in diameter and 10 mm to 32 mm in length. The relatively small size of these transponders allows them to be implanted into various sites of the animal such as the ear, armpit, upper lip, penial sheath or dewclaw (Lambooij, 1991). Once these transponders are implanted, they are virtually tamper proof; however, they must be removed by surgical procedures. Transponders have also been embedded into a plastic ear button (Allflex USA, Dallas-Ft. Worth, TX). Ear button transponders also serve as a source of visual identification, although the animal must be held in confinement for them to be read. The reliability of button transponders diminishes with age, and has an expected life span of 3 to 4 years.

In addition to tracking individual animal performance, the use of electronic identification also allows beef researchers to document daily feeding behavior unobtrusively and efficiently. Traditionally, animal scientists have used marking techniques such as brands, paints and ear tags to identify individual animals during behavioral observations including eating, drinking and lying (Augsburg, 1990). However, animal observation is extremely labor intensive and rarely includes all hours of the day (Gibb et al., 1998). These methods are also not practical to use when monitoring a large number of animals simultaneously. Electronic identification can be used to monitor an almost unlimited number of animals continuously throughout the feeding period. Furthermore, electronic identification and RF technology allow individual cattle to be monitored in a manner that does not alter behavioral attributes.

GrowSafe Behavior System. The recent development of an electronic feed bunk monitoring system (GrowSafe Systems Ltd., Airdrie, Alberta) that uses RF technology could be a key component in providing the beef industry with a way of tracking individual feeding behavior and performance characteristics. The GrowSafe behavior system enables individual animal feeding behavior to be monitored in large pen settings, which are typical of commercial production units. With this new system, researchers can monitor the number of visits to the bunk, the location along the bunk, and the length of time the animal is at the bunk. The system consists of a hard rubber mat lining the backside of the bunk equipped with an antennae (Figure 1), a reader panel, and a transponder encased in a plastic ear tag (e.g., Allflex USA) in the animal's ear (Figure 3). The antenna radiates a 134.2 kHz electromagnetic field so that once the tagged animals come within 50.4 cm of the antennae the transponder number is read and recorded. The GrowSafe System at the Lethbridge Research Center (Lethbridge, Alberta, Canada) records all individual transponders that are within 50 cm of the antennae every 5.25 seconds, although other systems will range from 5 to 6 seconds. The raw data recorded from the behavior system consists of a Julian date and time stamp, location, and EID of the animal. The GrowSafe behavior system was designed to research the behavior of cattle, and alone does not have the capability to measure feed intake. However, the behavior system has been coupled with an individual intake system composed of sections of a feed bunk with tubs suspended on load cells to record individual intake on a meal-event basis.

GrowSafe Intake System. The individual intake GrowSafe system is designed with a varying number of individual animal walk-in stalls with each stall having dimensions of 1.50 m long, 1.09 m wide, and 1.40 m tall, and equipped with adjustable bars to decrease width to 0.61 m for smaller animals. Each stanchion has a feed tub suspended on four load cells that continuously monitor the weight of the feed, and allows only one animal access to each section at a time (Figure 2). The feed intake for a single feeding event is determined by taking the weight of the feed present in the feed tub prior to the animal's arrival minus the amount remaining after it's departure. This is done for each meal event, and the total consumed for a 24-h period results in the estimate of the animal's daily intake. Each animal has access to a plastic rectangular feed tub situated on load cells that continually monitor changes in the tub weight, which is related to feed disappearance. The tub has dimensions of 0.97 m long X 0.38 m wide X 0.53 m high. The data recorded from the intake system consists of a date, time, location, and a weight value detected from the load cells.

Data management and assumptions

In order to derive the individual intake, the respective files from both systems must be compared. Once cattle are detected as being in the stall and consuming feed, date and time stamp information from the behavior system must be summarized into feeding events using the following assumptions. A time of 300 seconds has been used (Schwartzkopf-Genswein et al., 2001) to define a single feeding event. Once an animal was detected at the bunk, the beginning of an eating event was signaled. If the animal left and returned to the bunk, and the absence was less than 300 seconds, it was considered to be the same event. If the absence was longer than 300 seconds, it was considered to be a new eating event. However, if another animal came into the stall during that time it would be considered a new event. This time frame was used to define a meal criterion (Schwartzkopf-Genswein et al., 2001). This same time frame was selected by Sowell et al. (1998) based on their work with cattle, and de Haer and Merks (1992) based on their work in growing pigs. This transponder file is then be compared with the file recorded by the intake system. The times and locations in both files are used to establish an amount of feed consumed for the animal that is detected as being at a particular location.

The times recorded by the behavior system can be used to establish a feeding duration for each animal. Feeding duration is defined by two methods. The first method, "In-to-out" is the sum of time that is spent at the feed bunk between 300 second absences. In-to-out duration accounts for the time that an animal spends chewing feed or engaging in other social activities while standing at the bunk. The second method, "head down", is the sum of all 5.25 second data points when an animal's ear tag is within the read range of the antennae. Head-down duration does not account for the time that cattle spend chewing feed while standing at the feed bunk if the animal is over 50 cm from the antennae. Dr. Spencer Swingle also developed a method, "Swingle intensity" which is defined as (Head-down duration / In-to-out duration) * 100 (Streeter et al., 1999). Swingle intensity provides an indication of the proportion of time spent at the bunk dedicated to feed consumption. The premise for expressing feeding intensity in this manner was that the more aggressive animals would spend a greater proportion of time at the bunk consuming feed, and therefore would have superior ADG and feed intake. Feeding frequency is defined as the number of independent visits made to the feed bunk each day that are separated by at least a 300 second absence. Feeding event frequency can only be calculated when the bunk attendance data is summarized using the "in-to out" method, as the "head down" method does not use a meal criterion to establish specific feeding events.

Applications of GrowSafe

Morbidity. The GrowSafe System was initially evaluated for its ability to detect morbid cattle in a feedlot. Preliminary results indicated that the GrowSafe System may be able to identify potentially morbid animals 3 to 4 days before a pen rider would pull an animal based solely on visual determination of health status (Sowell et al., 1999; Streeter et al., 1999). Basarab et al. (2000) determined that steers treated three or more times for morbidity grew more slowly than steers not treated, or treated twice or less. Steers treated three or more times also exhibited lower feeding and drinking durations over the experiment than steers not treated, or treated twice or less for morbidity.

Daniels et al. (1999) also found that morbid calves spent 40 to 41% fewer minutes per day at the feed bunk than untreated and presumably healthy calves throughout two 21-d receiving trials. In addition, calves that had received a metaphalactic treatment tended to spend more time at the feed bunk than non-medicated control calves (Daniels et al., 1999). Individual animal intake was not measured in either of these studies, although it seemed unlikely that morbid calves that spent less time at the bunk could consume as much feed as untreated calves. The performance data suggested that untreated calves gained weight 22 to 29% more rapidly than calves pulled and treated for respiratory disease. Buhman (1998) investigated the effects of health status in two groups of heifers and found less dramatic effects of feeding duration based on health status overall; however, there were noted differences in feeding duration for d 11 to 27 between sick, pulled cattle and those not pulled or sick. They also found the existence of lung lesions at time of slaughter did not appear to be related to individual feeding or watering behavior during the first 62 d. Sowell et al. (1999) conducted two experiments to determine whether there were differences in feeding and watering behavior of newly received healthy versus morbid steers. Sowell et al. (1999) determined that time spent at the feed bunk between healthy and morbid steers was not consistent between the two trials, however frequency of visits to the bunk was consistent between both trials with healthy steers having more feeding bouts than morbid steers.

Feeding Behavior, Intake and Performance. Several research studies using the GrowSafe System have been conducted to document feeding behavior and its relationship to intake in feedlot cattle. Initial studies indicated that animals on a predominately barley silage diet spent 86.4 min·d-1 at the feed bunk with 84% of this time spent consuming feed (Schwartzkopf-Genswein et al., 1999). The GrowSafe System has also identified a poor correlation between feeding duration (head-down only) and ADG of individual animals (Streeter et al., 1999; Schwartzkopf-Genswein et al., 2002). Grouping animals into outcome groups based on ADG showed that animals which have spent the least amount of time at the bunk had the greatest ADG (Streeter et al., 1999). This reduced amount of time at the bunk might be associated with larger, less frequent meals, which is a feeding pattern that is believed to be associated with an increased incidence of *acidosis* (Cooper et al., 1999). The fact that these cattle expressed greater ADG suggests that there may be a need to rethink the genre behind the relationship concerning intake patterns, feeding behavior and animal performance.

Previous research concerning the effect of social status on animal performance relied heavily upon time consuming visual observations that were conducted at varying times throughout the day (Wagnon, 1966; Gonyou et al., 1981; Bowman and Sowell 1997). The GrowSafe system has the capability of providing researchers with a much better picture of exactly what influences social interactions among group-penned cattle have on eating patterns and general performance. Because the system records each animal's location at the bunk, it is possible to look at the stocking density along the bunk as well as diet preferences among individual animals. Studies have revealed that cattle do not eat at the same location for each meal event, but that they tend to graze along the feed bunk (Gibb and McAllister, unpublished data).

Feeding Behavior and Environment

GrowSafe is capable of providing a better depiction of weather conditions on animal performance. Extremes in temperature, precipitation, mud and wind have been associated with reduced intake and performance in feedlot cattle (Young, 1987; Stanton et al., 1995). Schwartzkopf-Genswein et al. (2003b) indicated Charolais and Holstein steers tended to spend less time at the bunk when the temperature was above 250C. Schwartzkopf-Genswein et al. (2003b) also reported that the effect of wind speed on bunk attendance was not clear, which may have been due to the windbreak fences that are used in their research feedlot. Streeter et al. (1999) reported that ambient temperature had a greater affect on bunk attendance than wind speed. Another study determined that ambient temperature was negatively related to feeding behavior and accounted for 81.7% and 70.8% of the variation in feeding head down time and duration, respectively (Basarab et al., 2000). A one degree Celsius decrease in temperature between the range of 100C and -200C resulted in a 0.87 minute/d increase in feeding head down time and a 1.37 minute/d increase in feeding duration. These results indicate that changes in thermal temperature are accompanied by corresponding changes in feeding behavior. However, Schwartzkopf-Genswein et al. (2003b) reported the overall effect of weather on bunk attendance frequency was small. Ambient temperature accounted for most of the variation with very small contributions from relative humidity, barometric pressure and wind speed. These same weather events did have a significant effect on bunk attendance duration.

Breed, Sex and Feeding Behavior. Schwartzkopf-Genswein et al. (2003b) found a significant interaction between breed and feeding regime when measuring bunk attendance frequency and duration. The lowest bunk attendance duration was exhibited by restricted-fed Charolais steers with ad libitum-fed Holstein steers visiting the bunk the most frequently. The longer time spent at the bunk by Holstein steers compared with Charolais steers was postulated to have been related to the fact that Holstein cattle have been selected for increased milk production, which is highly correlated with high DMI (Dado and Allen, 1994).

Schwartzkopf-Genswein et al. (2003a) found that heifers visited the feed bunk more frequently (17.68 versus 15.38 visits/d) and spent more time (124.9 versus 101.9 min/d) at the bunk than steers. This is in contrast to Chirase et al. (1991) who indicated that steers on a finishing diet spent more time eating than heifers (37.0 versus 30.0 min/d). Chirase et al. (1991) also found that steers made more visits to the bunk, although it was not significantly different. Schwartzkopf-Genswein et al. (2003a) reported that heifers had a higher average daily DMI than steers, although Owens et al. (1985) and Hicks et al. (1990) reported that steers consumed up to 3% more DM than heifers. The effects observed by Schwartzkopf-Genswein et al. (2003a) could have been due to the small sample size (n = 6), or the 10 kg larger weight of the heifers compared to the steers, and may not reflect the typical results found in an experiment with more animals.

Feeding Behavior and Additives. Several studies have documented small changes in feeding behavior as a result of adding ionophores such as monensin and salinomycin to the diet. Goodrich et al. (1984) documented decreased feed intake as a result of including monensin in a feedlot diet. Monensin is thought to decrease intake by approximately 1% (Stock et al., 1995) when fed at recommended levels. In contrast, Gibb et al. (2000a) observed that salinomycin did not cause as a great a decline in feed intake as monensin. Gibb et al. (2000a) found when using the GrowSafe system that cattle fed barley-based diets at 95% of ad libitum intake made more bunk visits/day, spent more time at the bunk/d, and exhibited less variation from day to day in bunk attendance when receiving monensin compared with salinomycin. The GrowSafe system has been modified to fit a mineral feeder to evaluate feed additives and mineral intake. Cockwill et al. (2000)

reported that 72% of the cows and 78% of calves in a pasture study did not consume the recommended dosage of fenbendazole over a 5-d period. This technology offers a way of evaluating supplements for cow/calf producers on an individual animal basis, and to determine if supplementation is cost effective. There are several other aspects of the feedlot industry such as grain processing, stocking density, feeding strategies and stress factors that would be possible applications for future research using the GrowSafe system.

Validation. In order to validate the GrowSafe system, Basarab et al. (2000) utilized visual observation in.comparison to data recorded by GrowSafe. Thirty-eight complete feeding events from thirty-eight different steers under commercial feedlot conditions were used. Feeding event start time, end time and duration were not different between the GrowSafe System and visual observation. The GrowSafe System accounted for 99.9%, 99.9% and 98.7% of the variation in feeding event start time, end time, and duration, respectively. The authors concluded that the GrowSafe system was highly accurate in determining the duration, start and end times of a feeding event. Schwartzkopf-Genswein et al. (1999) conducted a validation study similar results.

Feed Efficiency

Feeding management. There are many expenditures involved in beef cattle production and the greatest cost associated with livestock production is the cost of feed. Overall profitability is determined by the ability of the producer to reduce input costs in the most efficient manner. One of the most important factors is animal feed efficiency, which is influenced by several factors such as genetics, weather, and behavior. Feed efficiency varies from animal-to-animal and once scientists and producers have a better understanding of this component, feed costs could be lowered substantially through improved genetics and animal management. One method in which industry professionals try and influence animal efficiency is by manipulating intake patterns to improve feed efficiency. The practice of restricting feed intake in feedlot cattle to some degree, in relation to ad libitum levels, is termed "limit-feeding". The current theory is that feed efficiency can be enhanced by limit-feeding cattle, however this feeding method also changes eating patterns. Limit-fed cattle have two distinct periods of bunk attendance/d (0800 to 1200 h; and 1600 to 2000 h), whereas cattle fed at ad libitum levels attended the bunk more uniformly between 1600 and 2000 h (Gibb et al., 1998). Depending upon the geographic location, this method also hampers overall profitability in colder climates by not allowing animal's to be fed at adequate levels to gain an acceptable weight, due to the increased maintenance energy requirements associated with greater heat loss (McKinnon et al., 2001).

Genetic selection. Another method to improve feed efficiency of livestock is through genetic selection. Several studies suggest that temperament and other behavioral characteristics are slightly to moderately heritable (approximately 0.40; Hohenboken, 1986; Le Neindre et al., 1995). However, the inheritance of feeding behavior is still unclear due to the difficulty in collecting data for parameter estimation. Indirect selection of behavioral feed intake traits may have been practiced, resulting in more optimal feeding behavior as a correlated response to improved growth rate. Feed efficiency is a heritable trait which can be improved through genetic selection for more efficient animals over generations (Arthur et al., 2001).

Feed Intake. Feed intake is commonly used as a tool in management decisions, however presently intake is estimated on a per pen basis in commercial production systems. Feedlots typically use average daily intakes, calculated as the total feed delivered divided by the number of animals in the pen, which may be very different from the actual individual intakes of the constituent animals. This averaging also masks the variability that exists among intake of individual animals within a pen. This masking effect has been demonstrated when intakes of individually-fed cattle were averaged to simulate values that would be obtained in a pen setting (Stock et al., 1995). Using the individual feeding data of Britton et al. (1991), Larson et al. (1992) averaged individual intakes for each day as would occur in a commercial pen-feeding situation. Variation was reduced five-to-tenfold by treating individual data as an average, and treatment differences were eliminated.

Intake and Performance

Fluctuations in feed intake from day to day are thought to be a primary cause of digestive disturbances (Zinn, 1995) such as subacute acidosis, and result in decreased ADG. An experiment conducted by Galyean et al. (1992) indicated that cattle with feeding levels that fluctuated 10% from day-to-day had a 6% decrease in ADG and 7% poorer F:G compared with cattle fed at a constant level. The impaired performance in their study was attributed to acidosis arising from intake variation, despite the fact that ruminal pH was not measured. Stock et al. (1995) also concluded from the summation of several individual feeding trials that intake variation was a sign of subacute acidosis, which decreased performance. Results of these experiments have been widely accepted throughout the feedlot industry, although there is an increasing body of evidence that does not support such a relationship (Zinn, 1994; Stock et al., 1995; Soto-Navarro et al., 1997; Cooper et al., 1998; Owens et al., 1998).

In a finishing trial performed by Schwartzkopf-Genswein (unpublished data) cattle were fed at a constant level (ad libitum) and a fluctuating level (± 10% ad libitum over 3 days). There were no differences observed in intake, ADG, F:G or time at the feed bunk for either group. However, they did find in a corresponding metabolism study with the same feeding regimens that ruminal pH was 0.10 unit lower in the fluctuating group compared with constant-fed animals for a large portion of the day, suggesting a trend for lower pH; however, decreased pH did not appear to alter animal performance.

Acidosis

The North American feedlot industry has evolved into an intensively managed system where cereal grains are used as the primary energy source in finishing diets. This practice arose from the production of grains exceeding that of demand for the crop and therefore lowering the market value of the commodity. The combination of low price and high nutritive value resulted in these feeds being an economically favorable source of energy for finishing feedlot cattle. High-quality cereal grains, as with all feedstuffs, are subject to microbial fermentation in the rumino-reticulum of the stomach complex. The microbial fermentation rate of grains can progress too rapidly causing the rumen to accumulate fermentive acids and endotoxins (Stock, 2000). The excess production of these fermentation acids in the rumen can exceed the animal's ability to remove or buffer the acids. This condition is known as subclinical acidosis and is characterized with a ruminal pH of 5.2 to 5.6 (Cooper and Klopfenstein, 1996) while acute acidosis is characterized with a ruminal pH range of 3.9 to 4.5 (Dunlop, 1972). This range is below the level (6.2 to 5.8) for optimum fiber digestion by rumen cellulolytic bacteria. Several in vitro, in sacco and in vivo studies have demonstrated that the optimum range for cellulolytic bacteria to degrade cellulose is 5.8 to 6.2 (Russell and Wilson, 1996). Besides decreased fiber digestion, other physiological effects of acute acidosis include ruminal stasis mediated by VFA concentration (Ash, 1959; Stern, 1970; Svendsen et al., 1973), shock like symptoms resulting from endotoxin release from Gram negative bacteria, and diarrhea and dehydration resulting from increased osmolality within the digestive tract (Huber, 1976). Due to the volume of absorbed acids associated with acute acidosis, the plasma bicarbonate buffering system can be overwhelmed. The major accepted symptom associated with subacute acidosis is reduced feed intake and liver abcesses (Britton et al., 1991).

The immediate therapy for acidosis is to remove the source of readily fermentable carbohydrate, and provide a good-quality forage or diet with low amounts of readily fermentable carbohydrates. In severe cases, intravenous infusion of electrolytes or bicarbonate buffers can help. However, the most reliable prevention hinges on management techniques, such as gradual adaption to diets high in readily fermentable carbohydrates (Owens et al., 1998).

There appears to be considerable variation from one animal to another to metabolically cope with the problems associated with the rapid fermentation of high-grain diets (Dougherty et al., 1975; Brown et al., 2000; Schwartzkopf-Genswein et al., 2003). In a normal ruminal environment, the lactate concentrations usually do not exceed 10 mM (Harmon et al., 1985; Burrin and Britton, 1986). However, in acutely acidotic animals the ruminal lactate concentrations can exceed 50 mM (Dunlop, 1972; Nagaraja et al., 1985). When cattle are adapted to a high-grain diet, there is an accumulation of lactic acid followed by an accompanying increase in the number of lactate-utilizing bacteria. Hence a balance between lactic acid production and lactic acid utilizing bacteria is maintained. The reasons why some animals may experience some form of acidosis and others seem metabolically capable of handling the challenge remains unclear.

Intake Variation

Feed intake variation by feedlot cattle fed high-concentrate diets is presumed by most nutritionists and feedlot managers to either predispose or cause digestive disturbances such as acidosis and lead to decreased performance. Galyean et al. (1992) discovered that daily intake variation of 10% decreased gain and efficiency of steers compared with a constant amount of feed given per day in a limit-feeding scenario; however, they also reported that treatment differences narrowed as steers increased in BW. Stock et al. (1995) summarized several individual feeding trials and reported that intake variance was negatively correlated ($r = -0.28$) with gain:feed, implying that intake variation had some negative relationship with performance. Cooper et al. (1999) reported that within a limit-feeding system, intake variation of 1.4 kg/d increased subacute acidosis in steers as measured by the area of ruminal pH below 5.6. In contrast, Cooper et al. (1999) reported that the same steers fed under the same general conditions did not respond to imposed intake variation when fed at ad libitum levels of intake compared with being limit-fed. Cooper et al. (1999) reported that feed intake variation of up to 1.8 kg/d did not increase acidosis when fed at ad libitum levels, and concluded based upon several metabolism studies a decreased incidence of acidosis occurred with increased levels of intake variation. In contrast, Zinn (1994) found that intake variation had a positive affect on the performance of limit-fed steers, which may be related to the lowered risk of acidosis because the quantity of starch available for fermentation is decreased (Owens et al., 1998). However, there are many other factors involved in an animal's susceptibility to acidotic conditions.

Factors affecting Feed Intake

Traditionally, animal scientists have focused on the nutritional and physiological aspects of metabolic disorders and performance. This has resulted in many research studies focusing on ration formulations, feed processing techniques, and feeding management aimed at improving intake and performance while decreasing the occurrence of metabolic disorders (Schwartzkopf-Genswein et al., 2002). However, social structure, temperament and general feeding behavior may also play a large role in the amount of feed consumed by an animal. Cattle are typically fed in a commercial feedlot where social status and learning may affect eating patterns and the incidence of metabolic disorders (Galyean and Eng, 1998).

Feeding Management. The main goal of feeding management is to control feeding behavior and decrease the variation in intake of cattle. Research has revealed that the feeding behavior of feedlot cattle follows a diurnal pattern (Stricklin, 1986; Hicks et al., 1989), which corresponds to sunrise, sunset and/or time of feeding. Restricted and programmed feeding are the two most common approaches used by feedlot management today. Restricted feeding is generally used with cattle just going onto feed and finishing cattle. Restricted feeding is any method of feed intake management that restricts intake in relation to actual or anticipated ad libitum intake based on a pen average for the animals in question. Programmed feeding is typically used in growing scenarios and is a method that uses the net energy equations to calculate the quantities of feed required to meet maintenance requirements and a specific rate of gain. Both of these feeding programs have been used to increase feed efficiency (Plegge, 1987; Hicks et al., 1990; Murphy et al., 1994). However commercial application is limited by concerns related to negative effects on daily gain and carcass quality grade. Research findings suggest consistent improvements in F:G, decreased ADG and lower carcass quality grades when intake is restricted from 5 to 15% relative to pair-fed ad libitum controls in finishing cattle (Galyean, 1992).

Weather Effects. Weather conditions pose a tremendous burden for feedlot nutritionists and managers. Any disruptive weather condition which the animals are not acclimated to can alter thermoregulation and feed intake, and adversely affect performance (Basarab et al., 2000; Schwartzkopf-Genswein et al., 2002). Hahn (1995) reported that during periods of acclimation to high ambient temperatures feeding activities tended to shift toward fewer meals of longer duration, with less feed being consumed. Hahn (1995) also reported that as air temperature increased, the frequency of bunk visits decreased. Garner et al. (1987) reported an inverse relationship between air temperature and intake of a corn/corn silage finishing ration by feedlot cattle. They also reported a decrease in DMI when temperatures exceeded 270C and increased intake when temperatures dropped below 210C, but found no significant effects of barometric pressure or relative humidity on intake. Schwartzkopf-Genswein et al. (2003b) reported an effect of barometric pressure on bunk attendance duration and frequency of Charolais and Holstein steers during both restricted and ad libitum feeding. They found that during ad libitum feeding, duration was highest during low barometric pressure and lowest during high barometric pressure, with an opposite trend during restricted feeding. This same study also found, unexpectedly, that bunk attendance duration was lowest when wind speed was low (9.44 to 13.21 km·h-1) and increased as wind speed increased. However, the authors stated that the effects of wind could have been decreased as a result of the 60% porous wind fence encircling the pens in which the animals were housed. Other researchers have found that temperature has a greater impact on bunk attendance than wind (Streeter et al., 1999).

Ionophores. Ionophores have been used in commercial feedlots since 1975 when monensin was first introduced. The primary benefit associated with ionophores is an improvement in F:G and ADG (Vogel, 1995). Ionophores also help decrease the incidence of bloat and acidosis and prevent coccidiosis (Watkins et al., 1986). Goodrich et al. (1976) reported a decrease in feed intake when expressed as a percent of controls as the level of monensin increased from 5 to 30 g/ton. Brandt (1982) reported that feed intake of cattle decreased as the concentration of lasalocid in the diet increased. The magnitude of the decrease in feed intake depends on the concentration of the ionophore in the diet. Raun (1992) and Spires (1990) suggested that the effect of ionophores on feed intake would decrease as the level of energy in the diet increases. The mechanism by which ionophores affect feed intake is largely unknown. However, Baile et al. (1979) concluded that palatability of monensin was responsible for the decrease in feed intake suggesting a classical food aversion. Through the years, nutritionists and managers have noticed that the addition of monensin to the diet results in reduced variation in feed intake in feedlot cattle. This should yield a decrease in digestive disturbances and more consistent performance. Britton et al. (1991) compared the eating patterns of individually fed cattle consuming diets with 25 g/ton of monensin versus controls consuming diets with up to 100% concentrate. Feed weigh backs allowed for the calculation of actual feed intake and indicated that monensin reduced feed intake variation among steers within a day, during several days throughout the trial.

Grain Processing. The practice of feeding cereal grains to feedlot cattle has resulted in a cost effective way to finish cattle. However, not all cereal grains result in the same degree of growth performance in cattle. To capture maximum effect, some cereal grains are processed to varying degrees. Feedlots process grains for several reasons, but primarily to increase the energy availability to the animal. Some types of processing can destroy certain mycotoxins and improve the mixing capabilities which, when paired with bunk management, can improve animal production.

Owens et al. (1995) reviewed several years of data and determined that NRC values underestimated the value of processing on the ME value of corn and milo. They concluded that steam flaking reduced DMI and ADG but increased ME. Feed:gain decreased with more extensive processing, which indicates that energetic efficiency was improved by processing for barley, milo, oats and wheat. They found corn to be the exception, where whole grain corn was superior to dry rolled and high moisture forms (Owens et al., 1995). The extent of starch digestion in the rumen complex is much greater for wheat, oats, and barley than for corn or milo (Waldo, 1973). The processing of wheat, oats and barley should have less effect on site and extent of digestion than with corn and milo where more ruminal escape for starch is expected; however the processing of all cereal grains generally results in an improvement in starch digestion. The reduction of particle size by processing should be more beneficial to digestion by animals that tend to chew their feed less, such as cattle versus sheep. Processing grains can be very costly and to optimize some grains, extensive processing is necessary. With some grains the processing may not be economically justifiable. The ideal processing method, roughage level, roughage source and roughage moisture content for a feedyard will depend on the grain selected and the type of cattle being fed.

Summary

The use of technology that allows for the measurement of individual feed intake within a pen represents a significant advancement for the beef industry. This technology could be used as a selection tool for more efficient herd replacements. It could also provide early identification of sick animals, thus allowing more effective treatments to be administered. In addition, the effect of the environment on performance is now identifiable, allowing for the evaluation of this relationship in management practices. This technology will also allow for the evaluation of the effects of management practices such as transport, castration, and co-mingling on intake and performance.

Electronic identification is a proven technology in the retail sector, however the current lack of an information network allowing data to be collected and compiled throughout the livestock industry has restricted widespread adoption. Researchers have been using electronic identification as a research tool to identify sickness and allow treatment of animals earlier in the disease cycle than was previously possible. This technology is also capable of identifying animals with superior performance traits, and as a result can aid in the selection of genetically superior stock to use as replacements. The eminent country of origin labeling dilemma has many producers and industry professionals concerned. With the inclusion of electronic identification, cattle producers and managers would have a smoother transition into the "source verification" era.

Literature Cited

Albright, J. L. and Arave, C. W. 1997. The behavior of cattle. 1st ed. CAB International, New York, NY.

Ash, R. W. 1959. Inhibition and excitation of reticulo-rumen contractions following the introduction of acids into the rumen and abomasum. J. Physiol. 147:58-63.

Augsburg, J. K. 1990. The benefits of animal identification for food safety. J. Anim. Sci. 68:880-883.

Baile, C. A., C. I. McLaughen, E. L. Porter and W. Chalupa. 1979. Feeding behavior changes of cattle during introduction of monensin with roughage on concentrate diets. J. Anim. Sci. 48:1501-1508.

Basarab, J. A., D. Milligan, R. Hand and C. Huisma. 1997. Automatic monitoring of watering behavior in feedlot steers: Potential use in early detection of respiratory disease and in predicting growth performance. Can. J. Anim. Sci. 77 (abstr.): 554.

Basarab, J. A., D. N. Milligan, E. K. Okine, and R. Hand. 2000. Early detection of low growth performance in feedlot steers using feeding and watering behaviors. Alberta Agriculture, Food and Rural Development, Lacombe Research Center, 6000 C & E Trail, Lacombe, AB.

Bowman, J. G.. P. and B. F. Sowell. 1997. Delivery method and supplement consumption of grazing ruminants: A review. J. Anim. Sci. 75:543-550.

Brandt, W. E. 1982. Bovatec for improved feed efficiency and increased rate of weight gain in beef cattle fed in confinement for slaughter. Pages 69-84 in Bovatec Symposium Proceedings. Hoffman LaRoche, Indianapolis, IN..

Britton, R., R. Stock, M. Sindt, B. Oliveros and C. Parrot. 1991. A new feed additive and technique to evaluate acidosis in cattle. Nebr. Beef Cattle Rep. MP 56:55-58.

Brown, M. S., C. R. Krehbiel, M. L. Galyean, M. D. Remmenga, J. P. Peters, B. Hibbard, J. Robinson, and W. M. Moseley. 2000. Evaluation of models of acute and subacute acidosis on dry matter intake, ruminal fermentation, blood chemistry, and endocrine profiles of beef steers. J. Anim. Sci. 78:3155-3168.

Burrin, D. G. and R. A. Britton. 1986. Response to monensin in cattle during subacute acidosis. J. Anim. Sci. 63:888-893.

Cole, A. N. 1995. Intake control systems. Pages 156-161 in F. N. Owens, D. R. Gill, K. S. Lusby and F. T. McCollum, eds. Proceedings of the Symposium on Intake by Feedlot Cattle, Okla. Agric. Exp. Sta. P-942

Cooper, R., T. Klopfenstein, R. Stock and C. Parrott. 1998. Observations on acidosis through continual feed intake and ruminal pH monitoring. Nebraska Beef Cattle Rep. MP69-A:75-77.

Cooper, R. J., T. J. Klopfenstein, R. A. Stock, C. T. Milton, D. W. Herold and J. C. Parrott. 1999. Effects of imposed feed intake variation on acidosis and performance of finishing steers. J. Anim. Sci. 77:1093-1099.

Cooper, R. and T. Klopfenstein. 1996. Effect of Rumensin and feed intake variation on ruminal pH. Scientific Update on Rumensin/Tylan/Mycotil for the Professional Feedlot Consultant. Elanco Animal Health, Greenfield, IN.

Dougherty, R. W., J. L. Riley, A. L. Baetz, H. M. Cook, and K. S. Coburn. 1975. Physiologic studies of experimentally grain-engorged cattle and sheep. Am. J. Vet. Res. 36:833-835.

Dunlop, R. H. 1972. Pathogenesis of ruminant lactic acidosis. Adv. Vet. Sci. Comp. Med. 16:259-302.

Galyean, M. L., K. J. Malcolm-Callis, D. R. Garcia and G. D. Pulsipher. 1992. Effects of varying the pattern of feed consumption on performance by programmed-fed steers. N. M. Agric. Exp. Stat. Progress Rep. No. 78.

Galyean, M. L. and K. S. Eng. 1998. Application of research findings and summary of research needs: Bud Britton memorial symposium on metabolic disorders of feedlot cattle. J. Anim. Sci. 76: 323-327.

Garner, J. C., R. A. Bucklin and W. E. Kunkle. 1987. Weather effects on feed intake of feedlot cattle. American Society of Agricultural Engineers, St. Joseph, MI. Paper No. 87-4016.

Geers, R., B. Puers, V. Goedseels and P. Wouters. 1997. Electronic identification, monitoring and tracking of animals. CAB International, Wallingford, Oxon, UK.

Gibb, D. J. and T. A. McAllister. 1999. The impact of feed intake and feeding behavior of cattle on feedlot and bunk management. Pages 101-116 in Proc. 20th Western Nutrition Conf. Calgary, Alberta.

Gonyou, H. W. and W. R. Stricklin. 1981. Eating behavior of beef cattle groups fed from a single stall or trough. Appl. Anim. Ethology. 7:123-133.

Goodrich, R. D., J. G. Linn, J. C. Schafer and J. C. Meiske. 1976. Influence of monensin on feedlot performance- summary of university trials. Minnesota Cattle Feeder's Report B-214.

Hahn, G. L. 1995. Environmental influences on feed intake and performance of feedlot cattle. Pages 207-225. Symposium: Intake by Feedlot Cattle. Oklahoma State University, Stillwater, OK.

Harmon, D. L., R. A. Britton, R. L. Prior and R. A. Stock. 1985. Net portal absorption of lactate and volatile fatty acids in steers experiencing glucose-induced acidosis or fed a 70% concentrate diet ad libitum. J. Anim. Sci. 60:560-569.

Hicks, R. B., F. N. Owens and D. R. Gill. 1989. Behavioral patterns of feedlot steers. Okla. Agric. Exp. Sta. Res. Rep. MP-127:94-105. Oklahoma State University, Stillwater, OK.

Hicks, R. B., F. N. Owens, D. R. Gill, J. J. Martin, and C. A. Strasia. 1990. Effects of controlled feed intake on performance and carcass characteristics of feedlot steers and heifers. J. Anim. Sci. 68:254-265.

Huber, T. L. 1976. Physiological effects of acidosis on feedlot cattle. J. Anim. Sci. 43:902-909.

Lambooij, E. 1991. Automatic identification systems for farm animals. 1st ed. CEC, Brussels, Belgium.

Larson, E., W. Stroup, R. Stock, C. Parrott, R. Britton and S. Laudert. 1992. Rumensin/Tylan and feed intake variation. Nebraska Beef Cattle Rep. MP 58: 41-43.

McAllister, T. A., D. J. Gibb, R. A. Kemp, C. Huisma, M. E. Olson, D. Milligan and K. S. Schwartzkopf-Genswein. 1999. Electronic identification: Applications in beef production and research. Can. J. Anim. Sci. 80:381-392.

McAllister, T. A., C. L. Cockwill, J. McDowall, J. Yoakum, H. L. Stoddard and D. Tischer. 1998. Development of an indwelling ruminal transponder for electronic identification of beef cattle. J. Anim. Sci. 76(Suppl 1):277.

McKinnon, J. J., S. Gould, D. A. Christensen, J. Stookey, J. Campbell and E. Janzen. 2001. Limit feeding programs for Western Canada - Are our winters too cold? Proc. of the 22nd Western Nut. Conf., Saskatoon, Saskatchewan.

Murphy, T. A. and S. C. Loerch. 1994. Effects of restricted feeding of growing steers on performance, carcass characteristics, and composition. J. Anim. Sci. 72:2497-2507.

Nagaraja, T. G., T. B. Avery, S. J. Galitzer and D. L. Harmon. 1985. Effect of ionophore antibiotics on experimentally induced lactic acidosis in cattle. Am. J. Vet. Res. 46:2444-2452.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: A review. J. Anim. Sci. 76:275-286.

Owens, F. N., D. Secrist and D. R. Gill. 1995. Impact of grain sources and grain processing on feed intake by and performance of feedlot cattle. Pages 235-256 in F. N. Owens, D. R. Gill, K. S. Lusby and F. T. McCollum, eds. Proceedings of the Symposium on Intake by Feedlot Cattle, Okla. Agric. Exp. Sta. P-942.

Owens, F. N., D. S. Secrist, W. J. Hill and D. R. Gill. 1998. Effects of limited feed access time and day vs night feeding on performance and carcass characteristics of feedlot steers. Ok Agr. Exp. Stat. Anim. Sci. Res. Rep. MP-965:240.

Plegge, S. D. 1987. Restricting intake of feedlot cattle. In: F. N. Owens (Ed.) Symposium Proceedings: Feed Intake by Beef Cattle. Ok. Agric. Exp. Sta. MP-121:297-301.

Raun, A. P. 1992. Rumensin-then and now. Rumensin in the 1990's. Elanco Animal Health. Division of Eli Lilly and Co., Indianapolis, IN. Chapter A.

Russell, J. B. and D. B. Wilson. 1996. Why are ruminal cellulolytic bacteria unable to digest cellulose at low pH? J. Dairy Sci. 79:1503-1509.

Schwartzkopf-Genswein, K. S., S. Atwood and T. A. McAllister. 2002 Relationships between bunk attendance, intake and performance of steers and heifers on varying feeding regimes. Appl. Anim. Behav. Sci. 1874:1-10.

Schwartzkopf-Genswein, K. S., T. A. McAllister, D. J. Gibb, K. A. Beauchmin and M. Streeter. 2003a. Effect of feed fluctuation and delivery time on ruminal pH, performance and behavior of cattle. Can J. Anim. Sci. In Press.

Schwartzkopf-Genswein, K. S., R. Silasi and T. A. McAllister. 2003b. Use of remote bunk monitoring to record effects of breed, feeding regime and weather on feeding behavior and growth performance of cattle. Can. J. Anim. Sci. In Press.

Schwartzkopf-Genswein, K. S., C. Huisma and T. McAllister. 1999. Validation of a radio frequency identification system for monitoring the feeding patterns of feedlot cattle. Livestock Production Science. 60:27-31.

Soto-Navarro, S. A., G. C. Duff, C. R. Krehbiel, M. L. Galyean, and K. J. Malcom-Callis. 2000. Influence of rate of gain, feed intake fluctuation, and frequency of feeding on performance in limit-fed steers. Prof. Anim. Sci. 16:13-20.

Sowell, B. F., J. G. P. Bowman, M. E. Branine, and M. E. Hubbert. 1998. Radio frequency technology to measure feeding behavior and health of feedlot steers. Applied Anim. Beh. Sci. 59:277-284.

Sowell, B. F., M. E. Branine, J. G. P. Bowman, M. E. Hubbert, H. E. Sherwood and W. Quimby. 1999. Feeding and watering behavior of healthy and morbid steers in a commercial feedlot. J. Anim. Sci. 77:1105-1112.

Spires, H. R., A. Olmstead, L. L. Berger, J. P. Fontenot, D. R. Gill, J. G. Riley, M. I. Wray and R. A. Zinn. 1990. Efficacy of laidlomycin propionate for increasing rate and efficiency of gain by feedlot cattle. J. Anim. Sci. 68:3382-3391.

Stanton, T. L. 1995. Damage control strategies for cattle exposed to cold stress. Pages 289-299 in F. N. Owens, D. R. Gill, K. S. Lusby and F. T. McCollum, eds. Proceedings of the Symposium on Intake by Feedlot Cattle, Okla. Agric. Exp. Sta. P-942.

Stern, J. S., C. A. Baile and J. Mayer. 1970. Are propionate and butyrate physiological regulators of plasma insulin in ruminants? Amer. J. Physiol. 219:84-91.

Stock, R. A. 2000. Acidosis in Cattle : An Overview. Am. Assoc. Bov. Pract.33:30-37.

Stock, R. A., S. B. Laudert, W. W. Stroup, E. M. Larson, J. C. Parrott and R. A. Britton. 1995. Effect of monensin and a monensin and tylosin combination on feed intake variation of feedlot steers. J. Anim. Sci. 73:39-44.

Stock, R., T. J. Klopfenstein and D. Shain. 1995. Feed intake variation. Pages 56-59 in F. N. Owens, D. R. Gill, K. S. Lusby and F. T. McCollum, eds. Proceedings of the Symposium on Intake by Feedlot Cattle, Okla. Agric. Exp. Sta. P-942.

Streeter, M. N., M. Brainine, E. Whitley and F. T. McCollum. 1999. Feeding behavior of feedlot cattle: does behavior change with health status, environmental conditions and performance level. Pages 36-47 in Proceedings of the Plains Nutrition Council, Texas A&M Ext. Serv, April 1, San Antonio, TX.

Stricklin, W. R. 1986. Some factors affecting feeding patterns of beef cattle. Okla. Agric. Exp. Sta. Rep. 121:314-320.

Suzuki, S., H. Fujita and Y. Shinde. 1969. Change in the rate of eating during a meal and the effect of the interval between meals on the rate at which cows eat roughages. Anim. Prod. 11:29-41.

Svendsen, P. 1973. The effects of volatile fatty acids and lactic acid on rumen motility in sheep. J. Anim. Sci. 43:902-909.

Wagnon, K. A. 1987. Social dominance in range cows and its effect on supplemental feeding. Calif. Agric. Exp. Sta. Bull. #819 pp. 1-32.

Watkins, L. E., M. I. Wray, R. P. Basson, D. L. Feller, R. D. Olson, P. R. Fitzgerald, B. E. Stromberg and G. W. Davis. 1986. The prophylactic effects of monensin fed to cattle inoculated with coccidia oocysts. Agri-Practice 7:18-20.

Young, B. A. 1987. Food intake of cattle in cold climates. Pages 328-340 in Proceedings of the International Feed Intake Symposium. Oklahoma State University, Stillwater, OK.

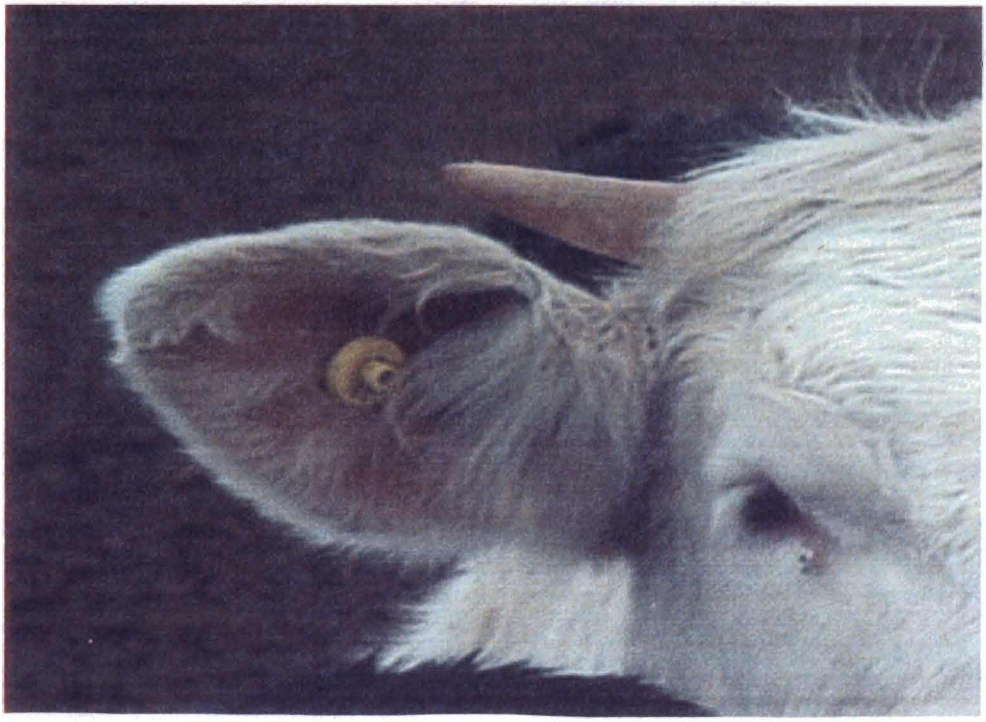
Zinn, R. A. 1994. Influence of feed intake fluctuation on feedlot cattle growth, performance and digestive function. Pages 36-47 in Proc. Southwest Nutrition and Management Conference. University of Arizona, Tuscon, AZ.

Zinn, R. A. 1995. Effects of levels and patterns of intake on digestive function in feedlot steers. Pages 167-174 in F. N. Owens, D. R. Gill, K. S. Lusby and F. T. McCollum, eds. Proceedings of the Symposium on Intake by Feedlot Cattle, Okla. Agric. Exp. Sta. P-942.

Figure 1. GrowSafe behavior monitoring system

Figure 2. GrowSafe individual feed intake system

Figure 3. Electronic identification tag



Chapter III

Relationship between feeding behavior and performance of feedlot steers

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ABSTRACT: Two hundred twenty-three Charolais-sired steers from two consecutive yr averaging 293 $\pm$ 41 kg for yr 1 and 349 $\pm$ 41 for yr 2 were used to evaluate the relationship between eating behavior and performance. Steers were blocked by BW and assigned to four feedlot pens. Pens were equipped with a feed intake system (GrowSafe Systems Ltd., Airdrie, AB) consisting of 5 individual stalls (1.09 X 1.40 X 1.50 m) allowing individual animal access to a feed tub (0.38 X 0.53 X 0.97 m) suspended on load cells. Radio frequency was used to record individual animal identification, time and duration during each bunk visit. Individual feed intake was recorded with the load cells at each individual stall for each meal event. Steers were weighed every 14 d and were fed barley silage/barley grain backgrounding (65 d) and finishing (107 d) diets ad libitum. Daily variation in DMI was calculated as the difference in animal consumption on two consecutive days. Steers were categorized as high, average or low ($\pm$ 1 STD DEV of the mean) into outcome groups for ADG and gain efficiency (G:F) to compare eating patterns and performance. Results suggested that steers with greater ADG and gain efficiency spent more time at the bunk and consumed more feed, even though they exhibited a slower eating rate (ER) than steers with a moderate or low ADG during the backgrounding phase. However, in the finishing phase high ADG steers exhibited a greater ER compared with average or low ADG steers. The overall results from this

experiment indicate that the eating behavior of steers with the greatest ADG and gain efficiency is variable from one phase to the next. The ability to identify animals that will have the greatest performance would allow animals to be classified into outcome groups, and thus provide better use of feedstuffs and a better control of intake in penned animals.

Key Words: Feedlot Cattle, Performance, Feeding Behavior

Introduction

Feeding behavior of cattle seems to be highly repeatable from day to day (Stricklin, 1987; Hicks et al., 1989) and follows a diurnal pattern, with peaks of activity around sunrise and sunset. The extent to which feeding behavior influences performance remains to be defined. There are many influences that can affect the eating behavior of feedlot cattle, such as temperament (Voisinet et al., 1997), weather (Rittenhouse and Senft, 1982; Hahn, 1995), bunk space (McKinnon et al., 2001) and bunk management strategies (Schwartzkopf-Genswein et al., 2003). Studies have shown that large variation in intake by cattle fed high-concentrate diets can cause digestive disturbances (Fulton et al., 1979; Britton and Stock, 1987). Galyean et al. (1992) have shown reduced performance resulting from intake variability with limit feeding, while others have shown intake variability of up to 1.8 kg/d does not increase acidosis or decrease performance of finishing steers fed at ad libitum levels (Cooper et al., 1999). Restricting feed access, as with limit-feeding scenarios, typically results in cattle becoming meal eaters (larger, less frequent meals; Schwartzkopf-Genswein et al., 2003). However, this practice may not be the best option for bunk management in colder climates, as colder winters would increase the maintenance energy needs of cattle and could decrease the energy available for gain (McKinnon et al., 2001).

Until recently, individual intake and behavioral data collection consisted of time consuming and labor intensive methods. Data is typically recorded for short amounts of time and on a limited number of animals that are usually individually penned, which would not typify the behavioral feeding patterns in a commercial pen setting. The use of radio frequency technology (GrowSafe Systems Ltd., Airdrie, AB) has more recently allowed the non-invasive and thorough collection of behavioral data. This system allows documentation of bunk attendance patterns and feed intake by individual cattle in large groups in settings that are typical of commercial feedlots. The GrowSafe system has also been coupled with an intake system to enable estimation of individual animal intake within a pen. The objective of this study was to better define the relationship between feeding behavior, intake and performance using radio frequency technology in cattle fed growing and finishing diets.

Materials and Methods

Animals

Charolais-sired steer calves (n = 227) from two consecutive years averaging 293 $\pm$ 41 kg (n = 74) for yr 1 and 349 $\pm$ 41 kg (n = 153) for yr 2 were used in a 187-d feeding trial in yr 1 and a 165-d feeding trial in yr 2 to document the relationship between feeding behavior, intake and performance. The experiment was initiated on November 30, 1999 and terminated on June 30, 2000 in yr 1, whereas in yr 2, the experiment was initiated on January 17, 2001 and terminated on July 17, 2001. Upon arrival, steers were blocked by BW, equipped with a radio frequency transponder (Allflex USA, Dallas Ft. Worth, TX) and assigned to one of two feedlot pens (37 steers/pen) in yr 1 and one of four feedlot pens (39 steers/pen) in yr 2. For yr 1, steers were vaccinated for hemophalus with SomnuStar PhJ (2 mL subcutaneous; Novartis, Mississauga, ON), bovine viral diarrhea (BVD) with Bar VacJ 3 (2 mL intramuscular; Boehringer-Engelheim, Burlington, ON), a clostridial injection of Fortress7 7 (5 mL subcutaneous; Bayer, Toronto, ON) and administered DectoMax7 for internal parasites (25 mL pour-on; Pfizer, London, ON). Boosters of SomnuStar Ph and Bar Vac 3 were administered 28-d later. For yr 2, steers were vaccinated for BVD, PI_3, and bovine respiratory syncytial virus (BRSV) with Resvac 47 (2 mL intramuscular; Pfizer, Kirkland, AB), blackleg, tetanus, black disease, pulpy kidney, enterotoxemia, and clostridia with Tasvax 87 (4 mL subcutaneous, Schering-Plough, Pointe Claire, QU), and administered DectoMax7 for internal parasites (25 mL pour-on; Pfizer, London, ON). Boosters of Resvac 47 and Tasvax 87 were given 28-d later. Records of all animals pulled for any medical treatment were documented. Animals were weighed every 14 d throughout each experiment. Animals were cared for under the guidelines established by the Canadian Council on Animal Care (1993).

Cattle had ad libitum access to water and feed during both years of the experiment. The cattle consumed diets consisting of barley grain/barley silage and supplement during the backgrounding, transition and finishing phases (Tables 1 and 2). In yr 1, the backgrounding diet was fed for 87 d, three transition diets were fed over a 14-d period, and the finishing diet was fed for 117 d. In yr 2, the backgrounding diet was fed for 43 d, four transition diets were fed for 23 d, and the finishing diet was fed for 99 d. Feed was delivered at 0900, 1300, 1500 and 1900 h during the backgrounding phase, and 0900, 1300 and 1500 h during the finishing phase for both years to accommodate ad libitum appetite. Diets were fed as total mixed rations using a feed wagon and delivered to each bunk in equal amounts throughout the day.

Housing and Feed Bunk Monitoring System

Feedlot pens measuring 40.2 X 27.4 m with a centrally located water system and 24.4 m of bunk space. Each pen was fitted with a GrowSafe monitoring system consisting of 5 individual stalls measuring 1.1 X 1.4 X 1.5 m with an adjustable width to allow individual access for smaller animals. Each stall had an individual feed tub (0.38 X 0.45 X 0.96 m) situated on load cells. Once an animal entered the stall, the transponder was detected by the antennae embedded in the rubber mat lining the back of the feed bunk. The transponder would identify an animal as being at a specific location for a duration of time until the animal left. The amount of feed that disappeared at that specific location and during that time was detected by load cells, and weights were recorded by a computer. This system has been described in detail (Schwartzkopf-Genswein et al., 2001).

Validation of the GrowSafe system was performed in the same fashion as reported by Schwartzkopf-Genswein et al. (1999). The system was checked weekly throughout the trial to ensure that all cells within the mat were functioning properly. This involved using an unassigned transponder and holding it within the read range of the antennae for 10 sec. The computer was checked to ensure that the transponder had been detected at the cell location at the specified time. The load cells were validated by placing a 10-kg weight in each tub at a specific time, and viewing the computer to ensure that the extra weight had been read on the scale file in that tub at that time. If any cells were inoperational, they were repaired and any data from that time was disregarded from analysis.

Data Processing and Analysis Assumptions

The data collected by the monitoring system consisted of two files, one animal and one scale file. The animal file included the animal electronic identification (EID), number of the transponder, read times and the location along the bunk where the signal was recorded. The scale file consisted of weights, location and times the weights were recorded. An in-house Oracle-based computer program was developed and utilized to compare the times and locations of the animal and scale files to arrive at a common location and time between the two files. This would establish that an animal was at a specific location at a certain time. The program was then able to arrive at start and end times for an event based on a meal criterion of 300 sec. These times were then compared using the in-house program to establish the weight of the feed at the onset and conclusion of each event and to assign the feed consumed to each individual animal. The total amount of feed consumed, as well as the duration and frequency of bunk attendance for each individual animal over a 24-h period, was compiled for statistical analysis.

Several assumptions with regard to data management were made in order to establish estimates of feeding duration, frequency and intake. First, all negative eating events were discarded. A negative eating event occurred when an animal would go to the bunk, and the scale file would show added weight during the time of that visit. This usually was the result of a steer scratching his chin on the tub or when feed was delivered to the pen. This would result in a negative value for that eating event on the scale file, and the event was removed. If a feeding event spanned across the change of day (i.e., midnight), the event as a whole would be assigned to the day which had the greatest portion of the entire event (> 50%). Duration at the bunk was divided between the two days according to the amount of time that took place in each day. The amount of feed consumed was also divided between the two days by assigning feed consumed in each respective day to that day=s total consumption.

Meal criterion was defined as a series of consecutive readings being detected by the system for the same animal. If there was a time lapse of more than 300 sec between the recordings, then the last recording was classified as the onset of a new eating event. If the recordings were within 300 sec of each other then it was considered the same event. In other words, the animal could leave the bunk for a time period of less than 300 sec, return to the bunk and it would be recorded as one continuous event. However, if another animal was detected at that location during that time, it was considered two separate eating events. All other situations were considered new eating events. This time frame used to define a meal criterion was selected based on the work of Schwartzkopf-Genswein et al. (2001). This same time frame was also selected by Sowell et al. (1998) for beef cattle, and de Haer and Merks (1992) for growing pigs. For this experiment, daily variation in intake (DVI) was calculated as the difference in DMI from one day to the next, and was expressed as an absolute value. Eating rate (ER) was calculated as the amount of feed DM consumed per min, and expressed as grams per min.

Steers were classified according to ADG (2.44 to 1.49; 1.47 to 0.93; and 0.92 to 0.53 for backgrounding, and 2.72 to 2.07; 2.06 to 1.41; and 1.40 to 0.90 for finishing) and G:F (0.33 to 0.21; 0.20 to 0.13; and 0.12 to 0.09 for backgrounding, and 0.31 to 0.24; 0.23 to 0.16; and 0.15 to 0.10 for finishing) into a high, average or low categories (∀ 1

SD from the mean), respectively. Subsequently, DMI, frequency of visits to the bunk, duration of visits to the bunk, ER, DVI, ADG and G:F for each animal were recorded.

Data were analyzed using generalized least squares (MIXED procedure of SAS; SAS Inst. Inc., Cary, NC). The model included ADG or G:F category as a fixed class variable with initial weight as a covariant, and sire and year served as random effects. The individual animal was considered to be the experimental unit for analysis. Means are presented as Least Squares means. The F-test protection level was set at $P < 0.05$. When the F-test was significant, the means were separated using the LSD procedure of SAS. The transition phase of both years was excluded from analysis due to the short duration in relation to the length of each trial. Following an analysis that revealed no year effect, data from each year were compiled into a single data set, categorized according to each variable of interest, and analyzed appropriately.

Results and Discussion

Average Daily Gain Category

Backgrounding phase. For the backgrounding phase, there were 32 steers classified as high, 164 as average and 31 as low ADG (Table 3). Average daily gain and G:F were 1.62, 1.19, and 0.83 kg/d, and 0.22, 0.16, and 0.13 kg of gain/kg of DMI for high, average and low ADG steers, respectively. During the backgrounding phase, steers classified as high and average ADG consumed more ($P < 0.05$) feed than low ADG steers. Daily variation in intake ($P = 0.27$) and frequency of visits to the bunk ($P = 0.27$) did not differ among ADG categories. Interestingly, high ADG steers spent a greater ($P < 0.05$) amount of time (duration) at the bunk consuming feed compared with average ADG steers, and average ADG steers spent more ($P < 0.05$) time at the bunk than low ADG steers. In contrast, high ADG steers had a slower ($P < 0.05$) ER compared with average or low ADG categories, whereas ER did not differ ($P > 0.05$) between average and low ADG category steers. These results suggest that steers with greater ADG and improved G:F spent more time at the bunk and consumed more feed, and exhibited a slower ER than steers with a moderate or low ADG. Schwartzkopf-Genswein et al. (2002) found a significant positive correlation ($r = 0.38$; $P < 0.001$) between bunk duration and ADG, which suggested that the longer the animals spent at the bunk the more feed they consumed. Gibb et al. (1998) also reported a positive ($r^2 = 0.57$) correlation between the total daily bunk attendance and DMI for steers consuming a finishing diet. In contrast, Keys et al. (1978) indicated that the relationship between intake and feeding duration was low. The non-significant difference found in frequency of visits to the bunk in the present experiment was unexpected based on the findings of

Hicks et al. (1989), who suggested that the frequency of eating was more related to animal performance than total time spent eating. However, in a study similar to the present experiment, Streeter et al. (1999) found that frequency of visits was not different among three ADG outcome groups. Streeter et al. (1999) suggested that days on feed was an important consideration that was not accounted for by Hicks et al. (1989).

Finishing Phase. Twenty one of the 32 steers classified as high ADG during the backgrounding phase were also classified as high ADG during the finishing phase (Table 3). There were 147 steers classified as average, and 35 classified as low ADG category steers for the finishing phase. Average daily gain and G:F were 2.01, 1.66, and 1.35 kg/d and 0.22, 0.19, and 0.17 kg of gain/kg of DMI, respectively, for high, average and low ADG steers. Steers classified as high ADG had greater ($P < 0.05$) DMI compared with average steers, and average steers had greater ($P < 0.05$) DMI than low ADG steers. Amount of DM consumed by steers in the present experiment was similar to DMI reported by Schwartzkopf-Genswein et al. (2002). Similar to the backgrounding phase, DVI did not differ ($P = 0.39$) among categories. In addition, daily bunk attendance frequency ($P = 0.85$) and duration ($P = 0.29$) were not different among categories. Streeter et al. (1999) found no statistical difference in frequency of visits between three ADG outcome groups, which supports the results found in this experiment. Although not statistically significant, high ADG steers spent 6.4% more time at the bunk each day than average or low ADG steers. These data are in contrast to the results of Streeter et al. (1999), who reported that steers with greater ADG had the shortest bunk attendance duration among outcome groups. The results of the present experiment were similar to Streeter et al. (1999) when sire was removed from the model, whereas the inclusion of sire reversed this trend, resulting in steers with greater ADG having the longest bunk attendance duration among outcome groups. Therefore, sire accounted for variation among steers in the present experiment. This reversal of trends might indicate a genetic predisposition exists for feeding behavior in cattle.

Eating rates were greatest for steers categorized as high ADG compared with average or low ADG steers (Table 3). The ER exhibited by the high ADG steers were similar to those reported by Schwartzkopf-Genswein et al. (2002). The interesting difference noticed in the present experiment was the change in the ER of the high ADG steers from the backgrounding phase to the finishing phase. During the backgrounding phase, high ADG steers had the lowest ER, whereas during the finishing phase the high ADG steers had the fastest ER. Similar to duration at the bunk, increased ER during the finishing phase might be the result of a genetically predisposed eating pattern. This switch in ER from the backgrounding to finishing phase was noticed when sire was included in the model. Perhaps some cattle are genetically predisposed to have a slower ER, which initially could prepare the rumen for a high-concentrate diet, and thus allow the animal to have a faster ER during finishing, and/or being less susceptible to ruminal acidosis.

Gain Efficiency Category

Backgrounding Phase. During the backgrounding phase, there were 32 steers classified as high ADG and 32 classified as high G:F. Of these steers, 22 were the same steers in both categories. When steers were categorized by G:F during the backgrounding phase, ADG and G:F were 1.55, 1.21, and 0.91 kg/d and 0.23, 0.16, and 0.12 kg of gain/kg of DMI for high, average and low G:F, respectively (Table 4). The most efficient animals (high G:F) consumed less ($P < 0.05$) feed than average or low G:F steers, whereas there was no difference between average and low category steers. Daily variation in DMI did not differ ($P = 0.95$) among high, average or low G:F category steers. High G:F steers made trips to the bunk more ($P < 0.05$) frequently compared with average or low category steers, with no difference between average and low category steers. Bunk duration did not differ ($P = 0.89$) among categories. Steers with the highest G:F had a slower ($P < 0.05$) ER compared with average or low G:F steers, and ER did not differ between average or low category steers.

Intake levels shown in the backgrounding phase of the present experiment are consistent with those reported by Hickock et al. (1992) for cattle of similar age and biological type. Basarab et al. (2000) reported that steers spent an average of 129.8 min/d at the feed bunk, similar to the duration times reported in the present experiment (117.06 min/d). In addition, Basarab et al. (2000) reported that steers had a bunk frequency of 6.6 visits/d, which is slightly greater than the number of visits reported in the present experiment. Gonyou and Stricklin (1981) reported that stall-fed cattle had higher eating rates (124 g/min versus 88 g/min) than bunk-fed animals. Stall-fed eating rates were similar to the results found in this experiment.

Finishing Phase. In the finishing phase, there were 31 steers categorized as high G:F, of which 17 were categorized as high G:F in the backgrounding phase of this experiment. Twenty two steers were categorized as both high ADG and high G:F in the finishing phase. There were 159 steers classified as average, and 37 classified as low G:F. Average daily gain and G:F were 1.94, 1.68, and 1.47 kg/d and 0.24, 0.19, and 0.15 kg gain/kg of DMI, respectively, for high, average and low G:F steers (Table 4). For steers classified according to G:F during the finishing phase, high G:F steers consumed the least ($P < 0.05$) amount of feed, and had the greatest ($P < 0.05$) ADG compared with average or low steers. High and average G:F steers had similar ($P > 0.05$) DVI, whereas low category steers had greater ($P < 0.05$) DVI than high or average category steers. High G:F steers made fewer ($P < 0.05$) visits to the bunk, and had the shortest ($P < 0.05$) bunk attendance duration compared with average or low category steers. Hicks et al. (1989) suggested that frequency of eating was more related to animal performance than total time spent eating; however, their study was performed on a limited number of animals and behavioral data was collected every 30 min over a 24-h period and for a limited number of days. Eating rate was not different among the three categories in the present experiment.

Table 5 shows the means of steers sired by sires which had offspring categorized as high ADG or G:F during both phases. There were 11 sires with offspring classified as high ADG steers during both phases, of which 9 sires also had offspring classified as high G:F during both phases. It appears that sire was confounded within a category, and that steers sired by genetically superior sirse for performance traits were also higher performing animals themselves.

Current data in the literature suggests that steers that consume feed at a constant level with the least amount of daily fluctuation will have greater ADG and gain efficiency and lower incidence of subacute acidosis (Galyean et al., 1992). However, data are generally based upon pen-fed averages and not actual individual animal data. In the present experiment, DVI was generally not different among categories, or was greatest for low G:F steers during the finishing phase, which supports the previous literature. It appears that the number of visits to the bunk is not as good of an indicator as time spent at the bunk (duration) in terms of predicting performance, which has also been reported by Streeter et al. (1999) and Schwartzkopf-Genswein et al. (2002). One reason may be due to the lower gaining steers having a slower ER than the steers with greater performance during the finishing phase. In addition, there is a poor relationship between bunk duration and DMI (Gibb et al., 1998; Schwartzkopf-Genswein et al., 1999). In contrast, Streeter et al. (1999) found that cattle with the highest ADG tended to spend the least amount of time at the feed bunk, as compared to average or low ADG steers. The results from the present experiment indicate the opposite trend. Our results also indicate that the ER of higher performing cattle changes from the backgrounding to the finishing phase. The results from the present experiment indicated that steers classified as high ADG on the backgrounding diet spent longer durations at the bunk and that 69% of these same cattle also tended to exhibit improved ADG and gain efficiency during the finishing phase. Consequently, selection on the basis of duration at the bunk during backgrounding may have applications as a tool for allocating animals to outcome groups for finishing.

Implications

Although considerable research has been done with feedlot cattle, results are often based upon pen-fed averages and are indicative of the average of the animals in a pen. This averaging effect can mask the individual variation among animals in an experiment. The overall results from this experiment indicate that the eating behavior of steers with the greatest ADG and gain efficiency is variable from one phase to the next. The ability to identify which group of animals within a pen that are the greatest performers could change the way in which many cattle are fed by placing them into outcome groups. This would allow better use of feedstuffs and a better control of intake in penned animals.

Literature Cited

Albright, J. L. and Arave, C. W. 1997. The behavior of cattle. 1st ed. CAB International, New York, NY.

Basarab, J. A., D. N. Milligan, E. K. Okine, and R. Hand. 2000. Early detection of low growth performance in Feedlot Steers using feeding and watering behaviors. Alberta Agriculture, Food and Rural Development, Lacombe Research Centre, Lacombe, AB.

Britton, R. A., and R. A. Stock. 1987. Acidosis, rate of starch digestion and intake. Okla. Agr. Exp. Sta. Res. Rep. MP-121:125-137.

Canadian Council on Animal Care. 1993. Guide to the care and use of experimental animals. V 1. E. D. Olfert, B. M. Cross, and A. A. McWilliam, eds. CCAC, Ottawa, ON.

Cooper, R. J., T. J. Klopfenstein, R. A. Stock, C. T. Milton, D. W.,Herold and J. C. Parrott. 1999. Effects of imposed feed intake variation on acidosis and performance of finishing steers. J. Anim. Sci. 77:1093-1099.

Cooper, R. J., T. J. Klopfenstein, R. A. Stock, C. T. Milton, D. W. Herold, J. C. Parrott. Effects of Imposed Feed Intake Variation on Acidosis and Performance of Finishing Steers. 1999. J. Anim. Sci. 77:1093-1099.

de Haer, L. C. M. and J. W. M. Merks. 1992. Patterns of daily food intake in growing pigs. Anim. Prod. Sci. 54:95-104.

Fulton, W. R., T. J. Klopfenstein, and R. A. Britton. 1979. Adaptation to high concentrate diets by beef cattle. Adaptation to corn and wheat diets. J. Anim. Sci. 49:775-784.

Galyean, M. L., K. J. Malcolm-Callis, D. R. Garcia, G. D. Pulsipher. 1992. Effects of varying the patterns of feed consumption on performance by programmed-fed steers. N. M. Agric. Exp. Station Progress Rep. No. 78.

Galyean, M. L., K. S. Eng. 1998. Application of research findings and summary of research needs: Bud Britton memorial symposium on metabolic disorders of feedlot cattle. J Anim Sci. 76:323-327.

Gibb, D. J., S. M. S. Moustafa, R. D. Wiedmeier and T. A. McAllister. 2001. Effects of salinomycin or monesin on performance and feeding behavior of cattle fed wheat or barley based diets. Can. J. Anim. Sci. 81: 253-261.

Gibb, D. J., T. A. McAllister, T. A., C. Huisma and R. D. Wiedmeir. 1998. Bunk attendance of feedlot cattle monitored with radio frequency technology. Can. J. Anim. Sci. 78: 707-710.

Gonyou, H. W. and W. R. Stricklin. 1981. Eating behavior of beef cattle groups fed from a single stall or trough. Appl. Anim. Ethology. 7:123-133.

Hickock, D. T., R. R. Schalles, M. E. Dikeman, and D. E. Franke. 1992. Comparison of feeding calves versus yearlings. Page 64 in Kansas State University Cattlemen=s Day.

Hicks, R. B., F. N., Owens, and D. R. Gill. 1989. Behavioral patterns of feedlot steers. Pages 36-39. Okla. Agric. Exp. Sta. Res. Rep. MP-127 Okla. State Univ., Stillwater, OK.

Keys, J. E., R. E. Pearson, P. D. Thompson. 1978. Effect of bunk stocking density on weight gains and feeding behavior of yearling Holstein heifers. J. Dairy Sci. 61:448-454.

McKinnon, J. J. 2001 Limit Feeding Programs for Western Canada-Are Our Winters Too Cold? Page 278-293 in Symposium Proceedings: 22nd Western Nutrition Conference. University of Saskatoon. Saskatoon, Saskatchewan.

Prawl, Z. I., F. N. Owens and D. R. Gill. 1998. Effects of limited feed access time and day vs night feeding on performance and carcass characteristics of feedlot steers. Page 40 in Ok. Agr. Exp. Stat. Anim. Sci. Res. Rep. MP-965. Okla State Univ., Stillwater, OK.

Rittenhouse, L. R., and R. L. Senft. 1982. Effects of daily weather fluctuations on the grazing behavior of cattle. In: Proc. Annu. Meet. West. Sect. Am. Soc. Anim. Sci. 33:305-307.

SAS Institute, INC. 1990. SAS/STAT User=s guide Statistics, Version 6. SAS INST. INC., Cary, NC.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, D. J. Gibb, D. H. Crews Jr., D. D. Hickman, M. Streeter, and T. A. McAllister. 2003. Impact of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. J. Anim. Sci. In Press.

Schwartzkopf-Genswein, K. S., C. Huisma and T. A. McAllister. 1999. Validation of a radio frequency identification system for monitoring the feeding patterns of feedlot cattle. Livest. Prod. Sci. 60: 27-31.

Schwartzkopf-Genswein K. S., S. Atwood, and T. A. McAllister. 2001. Relationship between bunk attendance, intake and performance of steers and heifers on varying feeding regimens. Appl. Anim. Behav. Sci. 76:179-188.

Schwartzkopf-Genswein, K. S., S. Atwood, T. A. McAllister. Use of radio frequency technology to determine the relationship between bunk attendance, intake and performance of steers and heifers on varying feeding regimens. 2002. App. Anim. Behav. Sci. 1874:1-10.

Soto-Navarro, S. A., G. C. Duff, C. R. Krehbiel, M. L. Galyean, and K. J. Malcom-Callis. 2000. Influence of feed intake fluctuation and frequency of feeding on performance in limit-fed steers. Prof. Anim. Sci. 16:13-20.

Sowell, B. F., J. G. P. Bowman, M. E. Branine and M. E. Hubbard. 1998. Radio frequency technology to measure feeding behavior and health of feedlot steers. Appl. Anim. Behav. Sci. 59:277-284.

Sowell, B. F., M. E. Branine, J. G. P. Bowman, M. E. Hubbert, H. E. Sherwood, and W. Quimby. 1999. Feeding and watering behavior of healthy and morbid steers in a commercial feedlot. J. Anim. Sci. 77:1105-1112.

Streeter, M. N., M. Branine, E. Whitley, F. T. McCollum. Feeding behavior of feedlot cattle: Does behavior change with health status, environmental conditions and performance level? Pages 36-47 in Proceedings of the Plains Nutrition Council, Texas A&M Ext. Serv, April 1, San Antonio, TX.

Stricklin, W. R. 1987. Some factors affecting feeding patterns of beef cattle. Page 314-317 in Symposium Proceedings: Feed Intake by Beef Cattle. Okla. Agric. Exp. Sta. Res. Rep. MP-121. Okla. State Univ., Stillwater, OK.

Voisinet, B. D., T. Grandin, J. D. Tatum, S. F. O=Connor, and J. J. Struthers. 1997. Feedlot cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments. J. Anim. Sci. 75: 892-896.

Zinn, R. A. 1994. Influence of fluctuation feed intake on feedlot cattle growth performance and digestive function. Page 77 in Proc. Southwest Nutrition and Management Conference. University of Arizona, Tucson, AZ.

Table 1. Backgrounding, transition, and finishing diets fed in year 1

Ingredient	Bk	Adaptation One	Two	Three	Finish
Days fed	87	4	5	5	117
Diet DM, %	54.5	59.4	65.2	72.3	77.4
Crude Protein, %	12.7	12.5	12.5	13.4	14.4
Net Energy Maintenance, Mcal/kg	1.64	1.82	1.66	1.74	2.00
Net Energy Gain, Mcal/kg	0.94	1.12	0.96	1.04	1.30

Table 2. Backgrounding, transition, and finishing diets fed in year 2

Ingredient	Bk	Adaptation One	Two	Three	Finish
Days fed	43	8	8	7	99
Diet DM, %	53.2	59.6	64.7	72.2	77.3
Crude Protein, %	12.6	12.7	13.3	13.1	13.8
Net Energy Maintenance, Mcal/kg	1.73	1.69	1.73	1.99	1.74
Net Energy Gain, Mcal/kg	1.03	0.99	1.03	1.29	1.04

Table 3. ADG category variable means for backgrounding and finishing phase

	Backgrounding Phase			Finishing Phase		
	High	Avg	Low	High	Avg	Low
n =	32	164	31	45	147	35
ADG	1.62 ± 0.02^{a}	1.19 ± 0.01^{b}	0.83 ± 0.03^{c}	2.10 ± 0.08^{a}	1.66 ± 0.08^{b}	1.35 ± 0.08^{c}
G:F	0.22 ± 0.08^{a}	0.16 ± 0.07^{b}	0.13 ± 0.08^{c}	0.22 ± 0.01^{a}	0.19 ± 0.01^{b}	0.17 ± 0.01^{c}
DMI	7.42 ± 0.42^{a}	7.18 ± 0.40^{a}	6.65 ± 0.42^{b}	9.40 ± 0.22^{a}	8.62 ± 0.17^{b}	8.01 ± 0.22^{c}
DVI	4.67 ± 0.50	4.65 ± 0.49	4.42 ± 0.50	4.04 ± 0.17	3.96 ± 0.16	3.86 ± 0.18
Freq	5.78 ± 0.33	5.90 ± 0.26	5.49 ± 0.34	5.29 ± 0.21	5.21 ± 0.13	5.32 ± 0.23
Dur	126.24 ± 3.69^{a}	116.95 ± 2.24^{b}	104.57 ± 3.78^{c}	72.76 ± 3.20	68.68 ± 2.29	68.06 ± 3.12
ER	66.11 ± 3.12^{a}	73.29 ± 2.16^{b}	78.07 ± 3.36^{b}	121.01 ± 26.07^{a}	117.06 ± 25.89^{a}	106.48 ± 26.07^{b}

[a,b,c] Means in the same row with different superscript differ significantly ($P < 0.05$).
G:F = kg of gain/kg of feed consumed.
DMI = the amount of feed consumed in 24-h on a DM basis.
DVI = difference in intake from one day to the next.
Freq = number of visits made to the bunk by an animal in 24-h.
Dur = time in minutes per 24-h spent at bunk by animal.
ER = g of feed consumed per minute.

Table 4. Gain efficiency category variable means for backgrounding and finishing phase

	Backgrounding Phase			Finishing Phase		
	High	Avg	Low	High	Avg	Low
n =	32	171	24	31	159	37
ADG	1.55 ± 0.07^{a}	1.21 ± 0.07^{b}	0.91 ± 0.07^{c}	1.94 ± 0.14^{a}	1.68 ± 0.13^{b}	1.47 ± 0.14^{c}
G:F	0.23 ± 0.04^{a}	0.16 ± 0.02^{b}	0.12 ± 0.04^{c}	0.24 ± 0.01^{a}	0.19 ± 0.01^{b}	0.15 ± 0.01^{c}
Intake	6.82 ± 0.46^{a}	7.20 ± 0.44^{b}	7.35 ± 0.46^{b}	7.86 ± 0.26^{a}	8.58 ± 0.20^{b}	9.20 ± 0.24^{c}
D/var	4.59 ± 0.52	4.64 ± 0.51	4.61 ± 0.52	3.95 ± 0.11^{a}	3.85 ± 0.08^{a}	4.20 ± 0.10^{b}
Freq	5.27 ± 0.32^{a}	5.86 ± 0.25^{b}	6.35 ± 0.34^{b}	4.61 ± 0.27^{a}	5.16 ± 0.18^{b}	5.96 ± 0.23^{c}
Dur	118.27 ± 4.44	117.07 ± 3.05	115.84 ± 4.66	65.52 ± 4.47^{a}	67.95 ± 3.79^{a}	73.96 ± 4.26^{b}
ER	68.14 ± 3.65^{a}	73.38 ± 2.79^{b}	72.82 ± 3.80^{b}	118.14 ± 24.66	116.48 ± 24.41	111.07 ± 24.59

^{a,b,c} Means in the same row with different superscript differ significantly ($P < 0.05$).
G:F = kg of gain/kg of feed consumed.
DMI = the amount of feed consumed in 24-h on a DM basis.
DVI = difference in intake from one day to the next.
Freq = number of visits made to the bunk by an animal in 24-h.
Dur = time in minutes per 24-h spent at bunk by animal.
ER = g of feed consumed per minute.

Table 5. Sire data for high category animals

	DMI	ER	Dur	Freq
Backgrounding Phase				
ADG Cat	7.27 ± 0.24	76.61 ± 3.16	121.86 ± 4.73	5.39 ± 0.32
G:F Cat	6.65 ± 0.31	79.12 ± 3.84	114.00 ± 8.34	4.82 ± 0.36
Finishing Phase				
ADG Cat	8.96 ± 0.25	102.75 ± 7.2	71.82 ± 4.01	4.40 ± 0.24
G:F Cat	8.20 ± 0.19	100.20 ± 8.90	68.17 ± 6.03	3.95 ± 0.26

DMI = the amount of feed consumed in 24-h on a DM basis.
Freq = number of visits made to the bunk by an animal in 24-h.
Dur = time in minutes per 24-h spent at bunk by animal.
ER = g of feed consumed per minute.

APPENDIX

The purpose of this appendix is to report the findings of a 2-wk validation study conducted at the Lethbridge Research Center to determine to accuracy of the intake values reported by the GrowSafe system. This validation served as a two-part validation, with part one being the feed truck validation to ensure that the truck delivered accurate amounts of feed. In order to validate the truck we compared the weight of actual feed delivered from the truck to target weights of 6 kg and 26 kg for 10 d. The results showed that 97.65% of target feed delivered was actually delivered for the 26 kg category. The 6 kg weight showed that 117% of target feed was delivered indicating that more feed was actually delivered than intended. There was an average excess of 1 kg per day extra delivered from the feed truck for the 6 kg category. The higher accuracy of the 26 kg category, which is more representative of target amounts, suggested that the feed truck was working properly.

There was also a validation done on the amount of feed consumed versus the amount of feed delivered to validate the intake software. The amount of feed the software indicated was consumed for each tub was compared to the amount of feed delivered from the truck for that tub. This was conducted every day for 2 wk, with the exception of a weekend that fell in the middle of the study. Over the course of the validation study, the GrowSafe system recorded 26,184.1 kg of feed as being consumed on an as fed basis. The truck delivered 26,849 kg of feed (as fed) and there were 747.4 kg of orts/wastage recorded. The subtraction of the orts/waste value from the delivered value resulted in 26,101.6 of feed (as fed) as being consumed when calculated manually. Subtracting the GrowSafe value from this reported manual value shoed that there were

82.5 kg (as is) more feed accounted for by the GrowSafe system than was calculated manually. This resulted in the GrowSafe system accounting for 100.3% of the feed. It appears that the GrowSafe system is an accurate and dependable technology for monitoring and recording individual animal feed intake.

VITA 2

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